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LYSINE AND FAT SUPPLEMENTATION
OF WEANLING PIG RATIONS

by

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies for acceptance, a thesis entitled "Lysine and Fat Supplementation of Weanling Pig Rations" submitted by Gerald Harvey Anderson, B.Sc., in partial fulfilment of the requirements for the degree of Master of Science.

ABSTRACT

Experiments were designed to study the addition of lysine and fat to swine rations and to study some of the interrelationships which may exist among lysine, protein, and energy in rations for weanling pigs. Three experiments, each of 6 weeks duration, were conducted with 23-day-old pigs averaging 5.9 kg in weight. Experiment 1 was factorially designed with three levels of supplemental L-lysine (0, 0.2, and 0.4%), two levels of added fat (0 and 5%), both sexes, and two breeds (Yorkshire and Lacombe x Yorkshire). Experiment 2 was similarly designed except that 0.6% L-lysine was also added as a supplement to the basal diet and only one breeding group, Hampshire x Yorkshire x Landrace, was used. The basal diets in both experiments contained 0.45% lysine and 14.2% crude protein. In Experiment 1, metabolism trials were conducted when the pigs were 5 and 9 weeks of age. Experiment 3 compared the four rations resulting in the best performance in the previous experiments with a 22% protein standard prestarter containing 1.18% lysine. These rations were fed to Hampshire x Yorkshire pigs. All pigs were fed at the University of Alberta Livestock Farm.

Supplemental lysine increased the digestibility of lysine and the retention of nitrogen. Lysine and nitrogen digestibility improved with the age of the pig. More energy and nitrogen was digested and more nitrogen was retained from the ration by the Yorkshire than by the Lacombe x Yorkshire pigs. Interactions showed these differences in breed occurred before the pigs reached 9 weeks of age. Digestibility of lysine increased with age of the male pigs but remained nearly constant for the female pigs which resulted in a sex x age interaction. The addition of fat did not

influence any of the metabolism measures.

In Experiments 1 and 2, supplemental lysine or fat increased daily gain and daily feed consumption. In Experiment 1, a fat x sex interaction indicated that the fat additions resulted in a greater response with the male pigs than with the female pigs. In Experiment 1, the breed of the pigs, and in Experiment 2, the sex of the pigs, did not influence daily gain or daily feed consumption.

Lysine supplementation improved the efficiency of feed utilization. A fat x sex interaction showed that fat additions improved the feed conversion of the male pigs but were of no benefit to the female pigs. Breed of the pig did not influence the feed:gain ratio.

A calorie:lysine ratio of 4000:1 (kcal digestible energy per kg per unit percentage lysine) was shown to be adequate for maximum efficiency of feed utilization, but a ratio of at least 3500:1 was needed for maximum gain.

Experiment 3 demonstrated that the crude protein content of swine rations can be lowered considerably without significantly influencing performance of the pigs if the essential amino acid content of the diet meets the requirements of the pig.

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INTRODUCTION

Changes in concepts relating to energy and protein nutrition have been responsible for some marked advances in the efficiency of swine production. Recognition that feed ingredients vary in digestible energy content has led to the use of high-energy rations for growing pigs. Increased energy level of the rations has resulted in decreased feed intake and improved efficiency of feed conversion. These facts have led to the hypothesis that proteins, minerals, and vitamins in the rations should be related to the energy content of the ration if maximum performance is to be achieved.

Work with poultry and rats has indicated that the levels of amino acids should also be related to the energy content of the ration. The validity of this concept has not been thoroughly tested in swine.

Recognition of the importance of amino acid quantity and balance in the ration has led to increased interest in amino acid supplementation of practical diets. Thereby, a better balanced protein is obtained, and efficiency of protein and feed utilization may be improved. However, supplementation of rations must be economical as well as nutritionally successful if such supplementation is to be applied. The two amino acids most frequently deficient in swine rations are lysine and methionine, and these are now produced relatively cheaply.

Because lysine is an essential amino acid that is often limiting in swine rations, experiments were undertaken during 1965 to study the effect of adding lysine and fat to rations for pigs and to study some of the interrelationships which may exist among lysine, protein, and energy in rations for this species.

LITERATURE REVIEW

The value of protein for monogastric animals, such as the pig, is associated with the level and balance of essential amino acids in this protein, as was first established by Osborne and Mendel (1914). Lysine is now considered to be one of the first limiting amino acids in pig diets (Homb, 1963).

Addition of Lysine to Pig Rations

The first experimental evidence that lysine is an essential factor for the growing pig was offered by Mertz, Shelton, and Beeson (1949). They reported that deficiency symptoms observed on a 23.5% protein ration containing 0.02% lysine were alleviated by the addition of 2.0% DL-lysine HCl.

Since 1949, researchers have attempted to quantify the lysine requirements of swine. Most of the work has pointed toward a requirement in weanling pigs of 0.6 to 0.7% lysine in the ration (Homb, 1963). The Subcommittee on Swine Nutrition of the National Academy of Sciences — National Research Council (1964) recommends a level of 0.75% L-lysine and 18% protein for the growing pig weighing 25 to 75 pounds. For 10 to 25 lb. pigs the suggested requirement is 1.07% lysine and 22% protein.

The discovery that lysine may be limiting in some pig rations has led to experimentation with the lysine supplementation of practical swine rations. Early researchers in this area were Blight and Powick (1951), Jensen et al. (1952), and Catron et al. (1953) who obtained differing results when lysine was added to corn-soybean meal rations.

Lysine supplementation of baby pig rations

Little research work has been done with lysine supplementation of rations for pigs 3 to 9 weeks of age. Bowland (1960) demonstrated that lysine additions to a basal wheat ration increased daily gain and daily feed

consumption and improved efficiency of feed utilization. Daily gain, feed consumption, and efficiency of feed utilization was 0.73 lb., 1.45 lb., and 2.02 lb., respectively, on a 14.3% crude protein ration composed of wheat plus 11.3% soybean meal plus 0.27% L-lysine. Without supplemental lysine, equivalent results were 0.43, 0.98, and 2.28 lb., respectively. Similarly, Magruder, Sherman, and Reynolds (1961) found that 0.1% lysine added to a 14% corn-soybean meal ration increased gain from 0.61 to 0.71 lb. per day, which was equivalent to gain on a 16% crude protein basal starter. Feed conversion was improved, but not significantly, when lysine was added.

Increasing lysine from 0.93 to 1.86% in a 16% protein corn-soybean meal diet did not improve gain in experiments conducted by Long, Hudman, and Peo (1962). Meade et al. (1965) found that smaller additions of lysine to a similar ration resulted in no difference in gains. Although Long et al. (1962) reported no response in efficiency of feed utilization, Meade et al. (1965) showed an improved feed:gain ratio as lysine was increased.

Lysine supplementation of growing and finishing pig rations

A thorough review of literature prior to 1963 was done by Homb (1963). He stated that the corn-soybean meal ration is usually a satisfactory source of lysine if the protein level of the diet is sufficient. Although the protein and lysine content of barley is much higher than it is in corn, barley rations often respond to lysine supplementation. One reason for this response is that barley rations require only a small amount of protein-rich feeds to raise the protein content to recommended levels. Response to lysine supplementation of barley diets may also result from the variability which occurs in the lysine content of the barley, as demonstrated by Pethybridge (1949).

Neilsen et al. (1963) compared 14% protein rations in which barley diets contained 3% soybean meal with corn diets supplemented by 18% of

soybean meal. Although lysine content in the barley-soybean meal rations was 0.02% higher than in the corn-soybean meal rations, a greater response was obtained from 0.05% supplemental lysine in the former diet. The authors stated that this indicates that the availability to growing swine of lysine in barley is less than it is in corn or soybean meal.

Others have obtained a response when lysine was added to corn-soybean diets (Jones and Pond, 1963), to barley-soybean meal diets (Soldevila and Meade, 1964), and to barley-wheat-soybean meal diets (Bowland, 1962a). However, Meade, Dukelow, and Grant (1966), using corn-soybean meal rations, and Reimer, Meade, and Grant (1964), using barley-soybean meal diets, concluded lysine supplementation to be of no value.

In general, if a diet supplies lower protein or lysine levels, or both, than recommended by the Sub-committee on Swine Nutrition of the National Academy of Sciences — National Research Council (1964), a response to lysine supplementation can be expected.

Addition of Fat to Pig Rations

The majority of research in this area has been done by adding fat to rations of varying protein content with no attempt to hold protein: energy ratios constant.

Fat supplementation of baby pig rations

Crampton and Ness (1954) have demonstrated that corn oil additions of 5% to 26 or 30% protein rations for pigs 10 to 56 days of age resulted in a non-significant increase in gain but had no effect on feed intake. Efficiency of feed utilization was significantly improved by 18% when corn oil was added.

The protein level of the ration has influenced the effect of adding fat to swine rations. If the protein content of rations for 3 to 8-week-old pigs was 15 or 20%, corn oil tended to cause a uniform improvement in

gain and feed utilization (Sewell, Thomas, and Price, 1961), as did beef tallow added to 19% protein rations fed to pigs 5 to 10 weeks of age (Lowrey et al., 1962). However, if 8% corn oil was added to a 10% protein diet or if 10% beef tallow was added to a 13% protein ration, gains were non-significantly depressed.

Lowrey et al. (1963) have shown that quality of the protein source is important. Corn oil additions to a 5% casein diet increased gains, whereas if the diet contained 5% gluten instead of casein, gains were depressed.

Gains have been reported to be unaffected (Peo et al., 1957) or depressed (Manners and McCrea, 1963; Eusebio et al., 1965) if lard is added to rations containing a wide range of protein and fed to baby pigs from 2 to 47 days of age. The feed conversion ratio was unchanged (Peo et al., 1957; Eusebio et al., 1965) or widened (Manners and McCrea, 1963).

Eusebio et al. (1965) demonstrated that the total gain of pigs fed lard was significantly less than that of pigs fed tallow, soybean oil, or no added fat in the ration. These results suggest that the effects of adding fat to a hog ration may depend upon the source of the fat.

Asplund, Grummer, and Phillips (1960) observed that stabilized white grease did not improve gain or efficiency of feed utilization if added to rations in which the protein:energy ratios are kept constant. Sewell et al. (1961) stated that a calorie:protein ratio of 50:1 to 55:1 (kcal productive energy per lb. per unit percentage of protein) produced maximum performance of 3 to 5-week-old pigs. Similarly, Manners and McCrea (1963) have linked the protein requirement of baby pigs with the caloric density of the diet.

Fat supplementation of growing and finishing pig rations

Kuryvial (1961) reviewed conflicting experimental evidence concerning the value of adding fat to growing and finishing swine rations. However, his research indicated a uniform increase in daily gain, decrease in total feed consumption, and improved efficiency of feed utilization when stabilized tallow was added at levels of 15 or 30% to rations containing three levels of protein (Kuryvial, Bowland, and Berg, 1962). Similarly, recent researchers (Clawson et al., 1962; Bayley and Lewis, 1963; Greeley, Meade, and Hanson, 1964; Seerley, Poley, and Wahlstrom, 1964) have found that fat additions to swine rations increased daily gain and improved the conversion of feed to gain.

Seerley et al. (1964) obtained greater increases in daily gain when energy additions were made to high protein than to low protein rations. Clawson et al. (1962) noted that a narrow calorie:protein ratio supported most rapid gain during early growth, but this same effect was not apparent during later growth periods.

The results of adding fat to swine rations appear to be dependent upon the alteration of the calorie:protein ratio. However, the work of Sewell et al. (1961) indicated that the pig is less responsive than some species to varying caloric concentration relative to the level of protein in the diet.

Influence of Protein and Energy on Response to Lysine

Studies of the influence of protein and energy on response to lysine have been done with swine ranging from 12 to 91 kg in weight.

Relation of lysine to protein

Some evidence indicates that there is a proportionality between the lysine requirement and the protein content of the ration. Brinegar

et al. (1950) reported lysine requirements of 0.6 and 1.2% of the total ration at respective protein levels of 10.6 and 22% for pigs of initial weight of 30 or 43 lb. fed for 28 days. Expressed as percentages of the total protein in the ration, these requirements are 5.5 and 5.7, respectively. Lysine requirement of 7 to 11-week-old pigs, expressed as a percentage of the protein, decreased from 9 at the 10% protein level to 6 and 4.5 on protein levels of 15 and 20% in one experiment conducted by Chance et al. (1958). However, in the second experiment, lysine requirements were 7, 4.7, and 4.5% of the dietary protein as the protein levels increased. McWard et al. (1959) found lysine requirements of 30 to 60-lb. pigs to be 5.6% of the dietary protein when the protein level was 12.8%, but 4.4% when the protein was increased to 21.7 per cent.

For pigs 56 to 100 lb., a lysine requirement of 5% of the protein was stated by Pfander and Tribble (1955). A greater response to 0.5% lysine was obtained on a 15% protein (0.5% lysine) ration for 22 to 65-kg pigs than on a 10% protein (0.5% lysine) diet (Robinson, 1965).

The above results indicate an influence of protein level of the ration on amino acid requirements. This relationship may be linear if the requirement for lysine is met at each given protein level. However, if protein is added in excess of the needs of the pig, the lysine requirement, expressed as a percentage of the protein, will decrease.

Relation of lysine to energy

The energy level of the ration may be more critical than protein level in determining optimum amino acid levels. For example, Gordon, Maddy, and Machlin (1958) demonstrated that the amino acid requirement of poultry, expressed as a percentage of protein, was constant over a wide range of protein content provided that the proportion of calories to

protein was kept relatively constant. Also, results of work done with poultry (Schwartz, Taylor, and Fisher, 1958) and with rats (Rosenberg and Culik, 1955) suggested that optimum lysine:energy ratios may exist. Therefore, lysine requirements should more precisely be expressed as a function of the energy level of the ration, rather than as a percentage of the ration.

Abernathy, Sewell, and Tarpley (1958) found that additions of stabilized beef tallow reduced the depression in rate of gain obtained when L-lysine monohydrochloride was added to 14 or 18% protein diets for pigs 40 to 110 lb. in weight.

The maximum performance of finishing pigs was shown by Robinson and Lewis (1964) to be on a 16% crude protein ration containing 2950 kcal digestible energy per kg of diet. The energy:lysine ratio (kcal digestible energy per kg per unit percentage lysine in the ration) was approximately 3500:1.

A consistent lysine requirement for maximum efficiency of gain, when the need is related to the available energy content of the diet, was demonstrated by Mitchell et al. (1965). The values ranged from 0.22 to 0.24% lysine in the diet per 1000 kcal of metabolizable energy per kg of diet for early growing pigs averaging from 16 or 22 kg initially.

Lysine, Nitrogen, and Energy Digestibility and Nitrogen Retention

Design of metabolism cages

Mitchell and Hamilton (1935) conducted one of the first metabolism studies with swine. Since that time the use of rectangular metabolism cages for pigs over 50 lb. has been successful (Crampton and Whiting, 1943; Watson et al., 1943; Hussar, 1958; Likuski, 1959; Kuryvial, 1961). For metabolism studies with smaller pigs, Bell (1948) has developed an

adjustible cylindrical cage and Kolari, Rutledge, and Hanson (1955) have designed a swine harness.

Effect of lysine supplementation on nitrogen and energy digestibility and nitrogen retention

Researchers discovered that lysine supplementation alone or along with methionine supplementation will increase nitrogen retention of baby pigs (Jones, Hepburn, and Boyne, 1961) and of growing pigs (Evans, 1960; Evans, 1961; Evans, 1962; Soldevila and Meade, 1964; Robinson, 1965). Other workers (Meade and Teter, 1956; Soldevila and Meade, 1964), however, have shown that the addition of L-lysine failed to improve nitrogen retention of growing swine. Although Long et al. (1962) reported an increase in nitrogen excretion of baby pigs fed a 16% protein basal ration supplemented with lysine, these results may have been due to the high level of amino acid added because lysine was increased from 0.93 to 1.86% of the diet.

Lysine supplementation increased digestibility of nitrogen in 21% protein groundnut meal rations fed to 25 to 50-lb. pigs (Jones et al., 1961). The same authors found digestibility of nitrogen was unchanged by lysine additions if the protein content of the rations was 12, 15, or 18 per cent. Evans (1960) showed that lysine plus methionine supplementation of all vegetable diets raised the digestible nitrogen coefficient for growing swine. However, in 1961 Evans reported that the digestibility of protein was not influenced by amino acid supplementation.

Effect of fat supplementation on nitrogen and energy digestibility and nitrogen retention

Asplund et al. (1960) observed that the inclusion of 10 or 20% stabilized white grease in the diet of 8-week-old pigs increased the apparent digestibility of ether extract and protein.

In contrast, Kuryvial and Bowland (1962) reported that 15 or 30% supplemental stabilized tallow had no effect on apparent energy or nitrogen

digestibility of rations or on nitrogen retention of 7 or 45-kg pigs. Similarly, Lowrey et al. (1962) discovered that 10% stabilized fat did not influence protein digestibilities of rations of pigs averaging 20 lb. in weight. In 1963 they showed that corn oil did not influence protein digestibility or retention of nitrogen when the source of nitrogen in the diet of 21-day-old pigs is casein.

Effect of age on nitrogen and energy digestibility and nitrogen retention

In 1951 Bell and Loosli demonstrated that the biological value of a protein decreases as pigs increase in weight above 15 kilograms.

More recently, researchers have become interested in factors influencing digestibility in the baby pig. Thus, we now know that there are changes in the ability of a pig to digest rations as it grows from 3 to 9 weeks of age. For example, Lloyd, Crampton, and MacKay (1957) and Combs et al. (1963) found the average apparent digestibility of dry matter, energy, crude protein, and ether extract of early weaning pig rations was higher for 7 than for 3-week-old pigs. Eusebio et al. (1965) observed that digestibility of fat, protein, and dry matter increased significantly between 3 and 6 weeks of age but remained relatively constant between 6 and 9 weeks of age.

Nitrogen loss in the urine has been noted to increase as the baby pigs become older and heavier (Hays et al., 1959; Rutledge, Hanson, and Meade, 1961; Long et al., 1962).

Two research groups (Combs et al., 1963; Eusebio et al., 1965) concluded that the major change in the digestive system of the pig occurred prior to 7 weeks of age. This change in the digestive system has been largely associated with an increase in enzyme activity in the digestive tract. Hartman et al. (1961) have shown that the proteinase activity of stomach tissue; lipase, amylase, and proteinase activity of pancreatic tissue; and maltase and sucrase

activity of intestinal tissue increased to 7 weeks of age.

Although considerable study has been done on the addition of lysine and fat to swine rations, the results, in general, have been variable. The relationships existing among lysine, protein, and energy have received little attention in the past. Therefore, further research is needed to establish these relationships and to establish the effects of adding lysine and fat to swine rations.

EXPERIMENTAL

Objectives

The major objective of these experiments was to study the addition of lysine to practical rations for weanling pigs.

Specific experiments were designed to study:

1) (a) Rate of gain and efficiency of feed utilization of 3 to 9-week-old Yorkshire and Lacombe x Yorkshire pigs fed six rations containing three lysine levels and two fat levels.

   (b) Lysine, protein, and energy digestibility and nitrogen retention of the pigs at 5 and 9 weeks of age.

2) Rate of gain and efficiency of feed utilization of 3 to 9-week-old Hampshire x Yorkshire x Landrace pigs fed eight rations containing four lysine levels and two fat levels.

3) Rate of gain and efficiency of feed utilization of Hampshire x Yorkshire pigs fed four of the above rations or the prestarter used for pigs from 3 to 6 weeks of age at the University Livestock Farm.

To achieve the objectives, the experiments were factorially designed with the factors being breed, sex, 0 and 5% fat, and 0.45, 0.65, and 0.85% lysine in Experiment 1. In Experiment 2 the factors were sex, 0 and 5% fat, and 0.45, 0.65, 0.85, and 1.05% lysine. Five rations and both sexes were arranged factorially in Experiment 3.

Formulation of Experimental Rations

The basal ration was formulated so that all nutrients except protein and lysine would meet the requirements of pigs weighing 10 to 25 lb. (4.5 to 11.4 kg) as defined by the Sub-committee on Swine Nutrition of the National Academy of Sciences — National Research Council (1964). The basal ration was calculated to be deficient by 0.62% in lysine and 5.6% in protein. The

calculated protein level was kept constant at 16.4% while adding lysine or fat. When adding fat, consideration was given to the fact that, when the energy content of a ration is increased, adjustments must be made to prevent the occurrence of a deficiency of minerals and vitamins which may result from a lowered feed intake (Sibbald et al., 1957; Likuski, Bowland, and Berg, 1961).

Normally, pigs at the University of Alberta Livestock Farm are fed a modified computed prestarter containing 3% fat from 3 to 6 weeks of age, followed by a modified standard starter for the next 3 weeks (Bowland, 1965). However, in these experiments the pigs were fed one ration for the entire experimental period from 3 to 9 weeks of age.

The formulation and composition of the rations are given in Tables 1 and 2. All rations were ground, mixed, and bagged at the University Livestock Farm elevator and stored in the Muttart swine barn.

Methods and Procedures

Three separate experiments were conducted.

1) Experiment 1 dealt with lysine, energy, and nitrogen metabolism studies with 48 swine of two breeding groups at 5 and 9 weeks of age. Information pertaining to rate of gain and efficiency of feed utilization for the 6-week period was also obtained.
2) Experiments 2 and 3 were conducted with 32 and 20 pigs, respectively, to obtain supplemental information on rate of gain and efficiency of feed utilization.

Experiments 1 and 2 were conducted during the months of May to August, 1965. Experiment 3 was conducted from September to November, 1965.

In all experiments the pigs were identified at birth by ear notching and treated routinely for anemia prevention by the injection of 2 ml of Pigdex 100 (contains 100 mg of injectable iron per ml) at 4 days of age. The male pigs were not castrated.

Table 1. Formulation of the rations on an air-dry basis

Ration no.		1	2	3	4	5	6	7	8	9
L-lysine (added)	%	0.0	0.2	0.4	0.6	0.2	0.4	0.6	0.8	0.0
Fat (added)	%	0.0	0.0	0.0	0.0	5.0	5.0	5.0	5.0	3.0
<u>Ingredients</u>										
Wheat		70.0	70.0	70.0	70.0	70.0	70.0	70.0	70.0	60.9
Barley		19.30	19.05	18.80	18.55	11.30	11.05	10.80	10.55	
Oat groats										4.1
Stabilized fat						5.0	5.0	5.0	5.0	3.0
Sucrose										5.0
Molasses										2.4
Dried skimmilk powder										10.0
Fishmeal (72%)										12.0
Meat meal (55%)										1.2
Soybean meal (44%)		1.6	1.6	1.6	1.6	2.0	2.0	2.0	2.0	
Linseed meal (37%)		6.0	6.0	6.0	6.0	8.0	8.0	8.0	8.0	
Ground limestone		1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.2
Dicalcium phosphate		1.0	1.0	1.0	1.0	1.44	1.44	1.44	1.44	
Iodized salt		0.5	0.5	0.5	0.5	0.6	0.6	0.6	0.6	0.5
Trace mineral mix*										0.15
Zinc sulphate		0.05	0.05	0.05	0.05	0.06	0.06	0.06	0.06	0.05
Vitamin B-complex mix**		0.10	0.10	0.10	0.10	0.12	0.12	0.12	0.12	0.20
Vitamin B_{12} (44 mg/kg)		0.05	0.05	0.05	0.05	0.06	0.06	0.06	0.06	
Vitamin B_{12} (19.8 mg/kg)										0.10
Methionine (90%)		0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	
Vitamins A and D_2***		+	+	+	+	+	+	+	+	
Antibiotic supplement TM-10		0.20	0.20	0.20	0.20	0.22	0.22	0.22	0.22	0.20
L-lysine monohydrochloride			0.25	0.55	0.75		0.25	0.50	0.75	

*Contains the following minerals per kg of mineral mix: cobalt carbonate, 2.28g; copper sulphate ($CuSO_4 \cdot 5H_2O$), 24.50 g; ethylene diamine dihydroiodide, 1.30 g; ferrous carbonate, 234.80 g; manganous oxide, 47.73 g; zinc oxide, 2.96 g; ground limestone, 686.43 g.

**Contains the following B vitamins per kg of vitamin mix: riboflavin, 4.4 g; calcium pantothenate, 8.8 g; niacin, 19.8 g; choline chloride, 21.45 g; folic acid, 132.0 mg.

***Rations 1-8: to supply 275,000 IU vitamin A and 55,000 IU vitamin D_2 per 100 kg.
Ration 9: to supply 440,000 IU vitamin A and 44,000 IU vitamin D_2 per 100 kg.

Table 2. Composition of the rations on an air-dry basis

Ration no.		1	2	3	4	5	6	7	8	9
L-lysine (added)	%	0.0	0.2	0.4	0.6	0.0	0.2	0.4	0.6	0.0
Fat (added)	%	0.0	0.0	0.0	0.0	5.0	5.0	5.0	5.0	3.0
Fed in experiments		1,2	1,2	1,2,3	2,3	1,2	1,2	1,2,3	2,3	3
Lysine (calculated)	%	0.45	0.65	0.85	1.05	0.45	0.65	0.85	1.05	1.30
Crude protein (calculated)	%	16.5	16.5	16.5	16.5	16.4	16.4	16.4	16.4	23.8
Digestible energy (calculated)	kcal/kg	3410	3410	3410	3410	3660	3660	3660	3660	3650
Lysine (analysis)	%(a)	0.44	0.70	0.90		0.48	0.70	0.85		
	(b)	0.46	0.71	0.86	1.01	0.52	0.70	0.87	1.05	1.18
Crude protein (analysis)	%(a)	14.1	14.8	15.0		14.7	14.9	14.8		
	(b)	14.2	14.5	14.8	14.9	14.6	14.8	15.1	15.3	22.2
Gross energy (analysis) kcal/kg	(a)	3790	3800	3780		4070	4070	4050		
	(b)	3790	3750	3860	3800	4080	4060	4110	4100	4140
Avg apparent digestible energy coefficients	%	87.2	86.3	87.0	86.8*	86.6	85.8	86.2	86.2*	
Digestible energy (analysis) kcal/kg	(a)	3300	3280	3290		3530	3490	3490		
	(b)	3300	3240	3360	3300	3530	3480	3540	3530	
Calorie:lysine ratio (analysis) (kcal digestible energy/kg/unit % lysine)	(a)	7500	4690	3660		7350	4980	4100		
	(b)	7170	4560	3910	3270	6790	4970	4070	3360	

[a] Analysis of rations fed to pigs on Experiment 1.

[b] Analysis of rations fed to pigs on Experiments 2 and 3.

*An average of the three preceding figures.

Feeding experiments

In Experiment 1, a total of 48 pigs were fed rations 1, 2, 3, 5, 6, and 7, as shown in Table 1. The lots were balanced with equal numbers of each of the Yorkshire and the Lacombe x Yorkshire breeds and with equal numbers of each sex. The pigs averaged 6.0 kg in weight when allotted.

In Experiment 2, rations 1 to 8 outlined in Table 1 were fed to 32 Hampshire x Yorkshire x Landrace pigs. The lots were balanced with two animals of each sex averaging 5.9 kg in weight.

In Experiment 3, rations 3, 4, 7, and 8 were compared to ration 9, the standard prestarter (Bowland, 1965). Twenty Hampshire x Yorkshire pigs, balanced with respect to sex in each lot, were allotted at an average weight of 5.8 kilograms.

All pigs were weaned at 3 weeks of age, allowed 2 days to become used to eating in individual feeders, and placed on trial at the average age of 23 days and at a minimum weight of 4.5 kilograms. The pigs were housed in the Muttart feeding barn at the University Livestock Farm. They were fed in individual feeding stalls for periods of 1 hr, three times daily, and ran together in groups of eight when not being fed. Automatic waterers were available except when the pigs were in the feeding stalls. The pigs were weighed weekly and individual feed consumption data recorded.

Metabolism experiments

All the pigs in Experiment 1 were placed in metabolism cages during the 5th and 9th week of age. Therefore, they had at least a week before the first digestibility and retention trial to become accustomed to the ration.

Metabolism studies were conducted at the University Livestock Farm in cages described by Hussar (1958). The cages were modified to limit the area of movement of the pigs (Diagram 1). This was done by placing a wooden

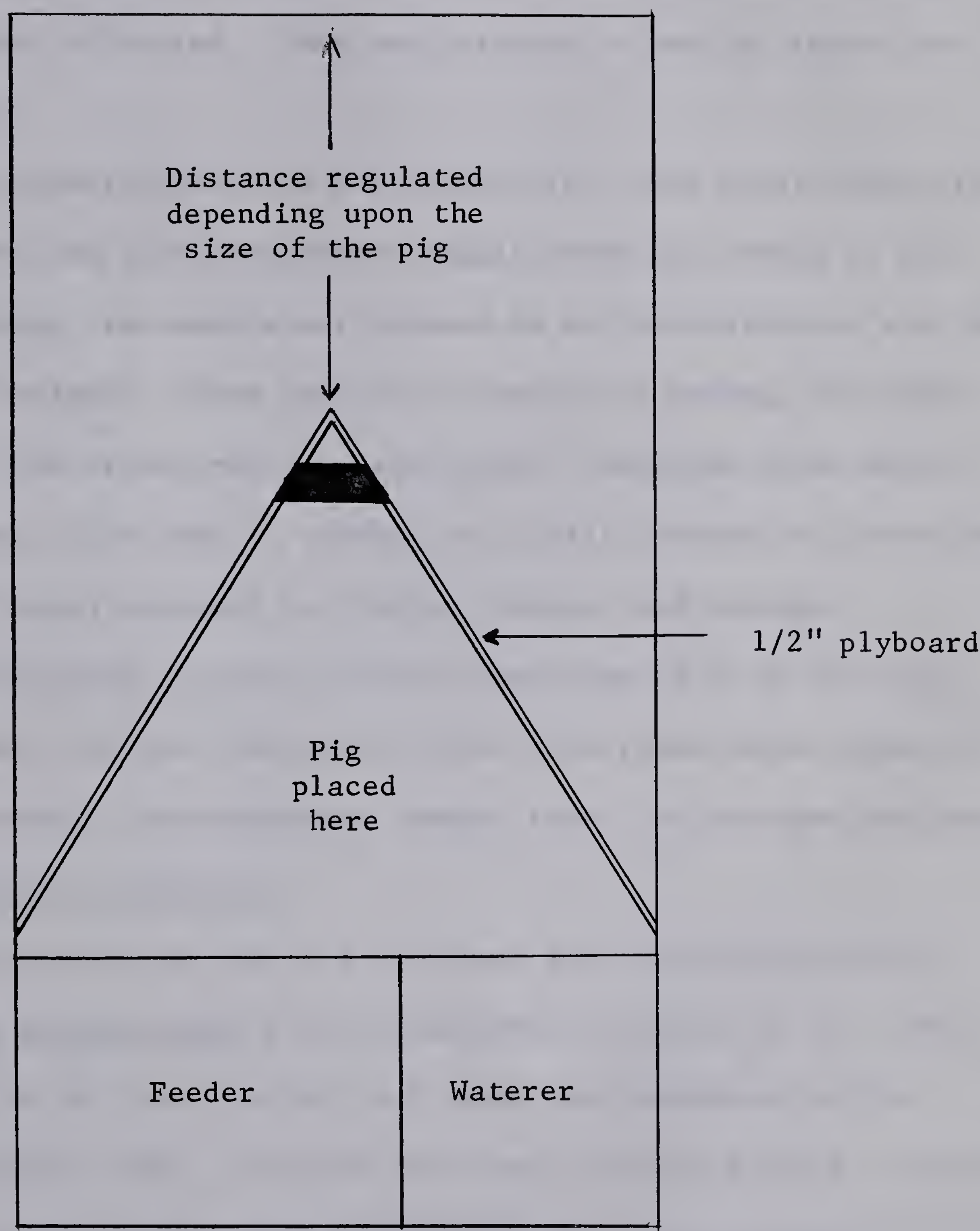

Diagram 1. Top view of a metabolism cage showing the position of the V board

V so that the opening of the boards was facing the feeder and the connected ends were toward the back of the cage. The distance between the closed ends and the back of the cage was regulated depending upon the size of the pig.

The pigs were given a 14-hr cage acclimatization period and then were on trial for 2 days during which time feed intake was recorded and total feces and urine were collected. They were allowed to eat for three 1-hr intervals per day.

Feces were collected twice in the 2-day trial. The total collection was weighed, mixed, and a representative sample taken for drying at 60 C. After 48 hr of drying, the sample was allowed 24 hr to equilibrate with air moisture and then weighed. From the loss in weight on drying, the total air dry weight of the feces could be calculated. The dried feces were ground through a no. 20 screen in a Wiley no. 1 Mill, sealed in plastic bags, and stored at 3 C until analyzed for lysine, energy, and nitrogen.

Urine was collected in plastic pails containing 25 ml of 50% H_2SO_4 (volume per volume). At the conclusion of the trial, the total volume of urine was measured and a representative sample taken for nitrogen analysis.

Methods of chemical analysis

Lysine analysis of the feed and feces was done microbiologically using *Leuconostoc mesenteroides* P 60 as described by Riesen et al. (1947). Nitrogen content of the diets, urine, and feces was determined by the Kjeldahl method (AOAC, 1960). Protein level was calculated using a conversion factor of 6.25. A Parr Oxygen Bomb Calorimeter was used to analyze the feed and feces for gross energy content.

Methods of statistical analysis

All data were analyzed statistically using the analysis of variance and Duncan's new multiple range test. The growth and feed data were also subjected to analysis of covariance with initial weight as the covariate

(Steel and Torrie, 1960). A probability of 0.05 was selected as the point of significance. The analysis was conducted on the IBM 7040 computer in the Department of Computing Science. Program BMD02V was used for the variance analysis and program BMD03V was used for the covariance analysis.

Data for one male Yorkshire pig on each of rations 1 and 6 in Experiment 1, and data for one male Hampshire x Yorkshire pig on ration 3 in Experiment 3 were missing. Values substituted for the missing data were the values obtained with the remaining male pig in the same lots. One degree of freedom was dropped for each substituted value.

Interactions of three or more factors were not discussed.

Although all the data were collected using the pound as the unit of measurement, the data were converted to metric units after the analysis was completed. Daily gain and daily feed data were changed to grams by multiplying by 454. The figures in the analysis of variance and the analysis of covariance tables of daily gain and daily feed were divided by 4.84 (2.2^2) to convert these data to the analysis which would have been obtained if the input data were in kilograms.

RESULTS AND DISCUSSION

Lysine, Nitrogen, and Energy Digestibility and Nitrogen Retention

The data for the apparent digestibility of lysine (ADL), nitrogen (ADN), and energy (ADE) and for the retention of nitrogen during the 5th and 9th week of age of the Yorkshire and Lacombe x Yorkshire pigs are given in Tables 3, 4, 5, and 6, respectively. The statistical analysis of these data is presented in Table 7. Table 8 contains the marginal means for each factor in the experiment as obtained by the analysis of variance.

Digestibility of lysine

Adding 0.2 and 0.4% lysine to the ration increased digestibility of lysine by 8.2 and 13.6%, respectively. As lysine was added in the crystalline form, presumably it would be readily absorbed without digestion. Therefore, digestibility of total lysine would be expected to rise as the proportion of the crystalline to the feed protein amino acid was increased in the ration.

Apparent digestibility of lysine coefficients were 2.3% more for pigs at 9 weeks than at 5 weeks of age. This improved digestibility of lysine is probably associated with the change in the proteinase activity of stomach tissue. Proteinase activity is low during the early weeks of a pig's life and increases rapidly to 8 weeks of age (Hartman et al., 1961).

The ability of the male pigs to digest lysine was increased from 74.3 to 79.2% with age, but lysine digestibility remained relatively constant, averaging 77.6%, for the female pigs. This interaction (Table 3A) indicates that the change in proteinase activity in the digestive system of female pigs may occur prior to 5 weeks of age.

Apparent digestibility of lysine coefficients were unaffected by fat levels in the ration or by breed of pig.

Table 3. Lysine digestibility (%) at 5 and 9 weeks of age for two breeds of pigs

Ration	Fat %	Lysine %	Sex	5 Weeks York[1]	5 Weeks Lac x York[2]	9 Weeks York	9 Weeks Lac x York
1	0	0.45	M	63.5	63.4	72.6	64.8
			M	63.5	63.4	72.6	72.3
			F	80.1	66.0	54.5	73.9
			F	75.8	78.5	67.6	72.7
	mean			70.7	67.8	66.8	70.9
2	0	0.65	M	79.5	66.9	79.7	81.2
			M	70.6	78.8	83.8	73.2
			F	83.1	74.3	79.2	81.7
			F	76.6	77.9	83.1	72.5
	mean			77.4	74.5	81.4	77.2
3	0	0.85	M	81.4	82.6	91.0	90.2
			M	76.5	80.1	85.1	86.2
			F	89.4	81.6	83.1	84.4
			F	82.9	76.6	84.1	85.9
	mean			82.6	80.2	85.8	86.7
5	5	0.45	M	74.1	56.9	85.1	71.7
			M	67.8	75.4	71.6	70.1
			F	73.8	76.6	65.8	72.9
			F	75.1	67.5	68.8	59.3
	mean			72.7	69.1	72.8	68.5
6	5	0.65	M	75.2	71.8	77.4	77.2
			M	75.2	81.6	77.4	81.9
			F	82.0	75.8	74.7	83.5
			F	78.3	77.1	84.7	83.4
	mean			77.7	76.6	78.6	81.5
7	5	0.85	M	84.9	86.5	79.1	81.1
			M	82.3	81.8	86.6	89.3
			F	78.6	75.7	86.6	86.8
			F	84.8	78.0	85.5	84.0
	mean			82.6	80.5	84.4	85.3

[1] Yorkshire.

[2] Lacombe x Yorkshire.

Table 3A. Sex and period effects on digestibility of lysine (%)

Sex		Period 1	Period 2	mean
Male		74.3	79.2	76.8
Female		77.8	77.4	77.6
	mean	76.0	78.3	

Digestibility of nitrogen

The failure of supplemental lysine to influence digestibility of nitrogen which was observed in this experiment has been found in previous studies by Jones et al. (1961). Several workers (Kuryvial and Bowland, 1962; Lowrey et al., 1962; Lowrey et al., 1963) have also reported that fat additions did not change the protein digestibility of rations.

Average ADN values for the 5th and 9th-week trials were 79.7 and 82.6%, respectively. This increase with age is in agreement with the work of Lloyd et al. (1957), Combs et al. (1963), and Eusebio et al. (1965). It also agrees with the theoretical as demonstrated by Hartman et al. (1961). They found that proteinase activity of stomach tissue of the pig increased steadily to 8 weeks of age. The rise in the average of ADN coefficients in the present study was 3.2% more for the crossbred pigs than for the Yorkshire pigs, resulting in a breed x period interaction (Table 4A). These results suggest that the Yorkshire pigs have a higher stomach tissue proteinase activity at 5 weeks of age than the Lacombe x Yorkshire pigs. In an average of both trials the ADN coefficients were 1.7% higher with the Yorkshire than with the crossbred pigs.

Sex of the pig did not influence nitrogen digestibility.

Table 4. Nitrogen digestibility (%) at 5 and 9 weeks of age for two breeds of pigs

Ration	Fat %	Lysine %	Sex	5 Weeks York	5 Weeks Lac x York	9 Weeks York	9 Weeks Lac x York
1	0	0.45	M	78.5	69.5	84.1	80.0
			M	78.5	76.6	84.1	83.5
			F	87.7	78.2	74.9	85.3
			F	86.6	84.2	81.2	80.3
	mean			82.8	77.1	81.1	82.3
2	0	0.65	M	82.6	77.8	83.4	83.1
			M	77.8	79.8	85.3	77.3
			F	83.5	77.4	80.8	84.9
			F	80.1	74.8	84.7	77.4
	mean			81.0	77.5	83.6	80.7
3	0	0.85	M	84.0	83.0	89.8	88.8
			M	76.3	78.2	83.7	83.7
			F	84.9	81.7	82.7	81.0
			F	81.7	69.5	79.2	83.7
	mean			81.7	78.1	83.8	84.3
5	5	0.45	M	85.8	77.5	89.3	82.0
			M	78.5	83.7	81.2	81.7
			F	84.6	81.9	79.3	82.0
			F	79.9	75.5	81.6	77.8
	mean			82.2	79.6	82.8	80.9
6	5	0.65	M	77.9	76.0	81.8	81.2
			M	77.9	79.6	81.8	81.3
			F	81.6	77.7	77.9	85.7
			F	84.4	79.2	86.3	85.4
	mean			80.4	78.1	82.0	83.4
7	5	0.85	M	79.5	85.3	78.4	79.3
			M	81.3	79.6	85.4	88.7
			F	76.0	72.4	83.8	85.3
			F	81.6	73.9	83.7	82.6
	mean			79.6	77.8	82.8	84.0

Table 4A. Breed and period effects on digestibility of nitrogen (%)

Breed	Period 1	Period 2	mean
Yorkshire	81.3	82.7	82.0
Lacombe x Yorkshire	78.0	82.6	80.3
mean	79.7	82.6	

Digestibility of energy

Neither the lysine or fat level in the ration nor the sex of the pig had any effect on the digestibility of energy. The fact that fat levels did not influence ADE coefficients supports the results of Kuryvial and Bowland (1962).

The average ADE coefficient for the Yorkshire pigs was 87.1% compared to 85.9% for the Lacombe x Yorkshire pigs. Bowland (1962b) also found ADE coefficients of growing and finishing pigs were influenced by breed, with the Lacombe pigs digesting a higher percentage of the gross energy than the Yorkshire pigs. In the present study, as the Yorkshire pigs aged, digestibility of energy decreased 1.6%, whereas an increase of 0.5% in digestibility of energy occurred when the crossbreds grew from 5 to 9 weeks of age. This caused a significant breed x period interaction (Table 5A).

Table 5. Energy digestibility (%) at 5 and 9 weeks of age for two breeds of pigs

Ration	Fat %	Lysine %	Sex	5 Weeks York	5 Weeks Lac x York	9 Weeks York	9 Weeks Lac x York
1	0	0.45	M	89.0	84.2	88.4	86.4
			M	89.0	84.4	88.4	86.1
			F	92.0	85.0	83.0	89.0
			F	90.4	90.0	84.5	85.6
	mean			90.1	85.9	86.1	86.7
2	0	0.65	M	87.9	85.7	87.1	87.3
			M	86.3	86.9	88.1	83.2
			F	89.2	84.6	86.1	87.9
			F	86.7	83.5	87.0	82.7
	mean			87.5	85.2	87.1	85.3
3	0	0.85	M	89.3	89.4	90.3	89.7
			M	84.8	84.5	88.4	87.8
			F	89.9	87.9	85.3	83.8
			F	87.3	82.7	84.5	86.8
	mean			87.8	86.1	87.1	87.0
5	5	0.45	M	91.5	84.7	89.7	85.2
			M	87.5	89.1	86.1	86.5
			F	89.5	87.4	84.3	86.4
			F	86.4	83.4	86.1	82.3
	mean			88.7	86.2	86.6	85.1
6	5	0.65	M	86.1	85.0	84.2	85.0
			M	86.1	85.4	84.2	83.8
			F	87.4	84.3	82.9	87.1
			F	89.2	86.5	88.6	86.6
	mean			87.2	85.3	85.0	85.6
7	5	0.85	M	86.7	90.1	84.4	85.1
			M	87.1	86.7	88.3	89.7
			F	84.9	81.4	87.4	88.0
			F	85.9	82.5	85.1	85.5
	mean			86.2	85.1	86.3	87.1

Table 5A. Breed and period effects on digestibility of energy (%)

Breed	Period 1	Period 2	mean
Yorkshire	87.9	86.3	87.1
Lacombe x Yorkshire	85.6	86.1	85.9
mean	86.8	86.2	

Retention of nitrogen

Retention of nitrogen increased significantly by an average of 4.8% with each increasing level of lysine, indicating that the pig was able to utilize more of the nitrogen as the amino acid balance improved. These results are in accordance with those of Jones et al. (1961).

These studies found that fat supplementation did not affect the amount of nitrogen excreted. Previous researchers (Kuryvial and Bowland, 1962; Lowrey et al., 1963) have reported similar observations.

The retention of nitrogen was also independent of the sex of the pig.

The Yorkshire pigs were again the superior breed if the criterion of measurement was the amount of nitrogen retained. They retained 3.1% more of the gross nitrogen consumed than did the Lacombe x Yorkshire pigs.

A breed x period interaction was associated with a decrease in nitrogen retention of the Yorkshire pigs, but a corresponding increase for the cross-breds, from the 5th to the 9th week of age (Table 6A). Possibly the Lacombe x Yorkshire pigs had a higher nitrogen requirement so that nitrogen was not in excess for the 9-week-old pigs of this breeding group. In general, nitrogen retention has been observed to decrease as the pigs age and become heavier (Hays et al., 1959; Long et al., 1962; Rutledge et al., 1961).

Table 6. Retention of gross nitrogen (%) at 5 and 9 weeks of age for two breeds of pigs

Ration	Fat %	Lysine %	Sex	5 Weeks York	5 Weeks Lac x York	9 Weeks York	9 Weeks Lac x York
1	0	0.45	M	55.3	40.2	51.3	47.5
			M	55.3	25.9	51.3	46.9
			F	61.9	30.4	41.4	52.5
			F	66.2	37.1	38.5	50.2
	mean			59.7	33.4	45.6	49.3
2	0	0.65	M	43.9	49.1	54.8	61.4
			M	53.6	51.8	51.4	46.0
			F	63.7	50.8	57.7	49.8
			F	50.2	42.4	59.2	49.8
	mean			52.8	48.5	55.8	51.8
3	0	0.85	M	65.2	48.8	61.0	65.0
			M	40.0	60.6	59.9	59.1
			F	67.0	61.1	52.9	51.0
			F	64.0	49.0	42.1	59.1
	mean			59.0	54.9	54.0	58.6
5	5	0.45	M	53.5	43.2	48.0	44.6
			M	50.5	58.4	51.4	50.5
			F	42.4	44.2	40.6	45.8
			F	54.2	48.7	39.8	49.6
	mean			50.2	48.6	45.0	47.6
6	5	0.65	M	49.1	60.1	51.1	52.1
			M	49.1	52.4	51.1	50.3
			F	69.6	46.3	54.1	56.8
			F	61.1	47.0	47.6	48.7
	mean			57.2	51.4	51.5	52.0
7	5	0.85	M	59.2	53.0	53.5	52.0
			M	63.7	57.7	59.6	68.0
			F	56.7	52.0	64.0	58.6
			F	48.1	55.1	61.7	55.7
	mean			56.9	54.4	59.7	58.6

Table 6A. Breed and period effects on retention of nitrogen (%)

Breed	Period 1	Period 2	mean
Yorkshire	56.0	51.9	53.9
Lacombe x Yorkshire	48.5	53.0	50.8
mean	52.3	52.4	

Table 7. Metabolism experiment — mean squares obtained by analysis of variance

	df	Digestibility: Lysine	Digestibility: Nitrogen	Digestibility: Energy	Retention of gross nitrogen
Total	91				
1 Breed	1	37.12	67.00*	36.38**	238.14*
2 Period	1	126.27*	211.82**	7.10	0.40
3 Lysine	2	1498.58**	3.91	6.95	738.12**
4 Fat	1	11.28	0.02	9.44	14.42
5 Sex	1	16.58	3.38	14.18	10.01
Interactions					
12	1	38.38	60.48*	25.32*	438.61**
13	2	2.03	3.39	3.70	41.85
14	1	0.00	10.53	2.84	90.87
15	1	0.13	4.86	0.41	58.28
23	2	42.80	19.23	9.63	12.19
24	1	2.25	0.03	0.00	22.42
25	1	162.50*	21.66	2.98	84.75
34	2	10.98	5.12	0.30	0.06
35	2	23.20	30.17	13.40	33.58
45	1	21.38	1.31	0.06	13.80
123	2	2.04	1.39	1.18	109.84
124	1	1.06	3.30	0.52	118.37
125	1	95.40	78.48*	19.89*	183.71*
134	2	41.64	4.03	1.36	103.07
135	2	41.60	16.86	7.76	120.83*
145	1	1.02	2.41	2.77	0.51
234	2	1.53	1.18	1.47	57.36
235	2	113.51*	36.06	4.85	4.34
245	1	67.17	54.00	24.71*	152.01*
345	2	23.68	34.25	10.30	17.55
1234	2	21.62	11.39	4.59	130.43*
1235	2	9.61	0.47	0.19	37.99
1245	1	19.71	1.13	0.79	22.62
1345	2	0.17	1.53	1.41	1.75
2345	2	13.67	17.72	5.95	80.11
12345	2	16.38	1.13	0.37	114.38
Error	44	26.05	13.54	4.53	36.05

*Significant at $P < 0.05$.

**Significant at $P < 0.01$.

Table 8. Marginal means of digestibility and retention data

Variables	Categories	Digestibility Lysine %	Digestibility Nitrogen %	Digestibility Energy %	Retention of gross nitrogen %
Breed	York	77.8	82.0	87.1	53.9
	Lac x York	76.6	80.3	85.9	50.8
Period	1	76.0	79.7	86.8	52.3
	2	78.3	82.6	86.2	52.4
Lysine	0.45%	69.9	81.1	86.9	47.4
	0.65%	78.1	80.8	86.0	52.6
	0.85%	83.5	81.5	86.6	57.0
Fat	0.0%	76.8	81.2	86.8	51.9
	5.0%	77.5	81.1	86.2	52.7
Sex	Male	76.8	81.3	86.9	52.6
	Female	77.6	81.0	86.1	52.0

Daily Gain, Daily Feed, and Efficiency of Feed Utilization — Experiment 1

Table 9 contains the average daily gain, the average daily feed consumption, and the efficiency of feed utilization data for the Yorkshire and the Lacombe x Yorkshire pigs. The statistical analysis of these data is presented in Table 10 and the marginal means are given in Table 11.

Daily gain

A response of 64 g increase in gain was obtained with each increasing level of lysine in the diet. These results agree with earlier work by Bowland et al. (1960) and Magruder et al. (1961). From these results the lysine requirement of baby pigs on a 14.9% protein ration adequate in all other nutrients is at least 0.88% of the ration or 5.93% of the protein. The latter figure supports the work of Brinegar et al. (1950), Chance et al. (1958), and McWard et al. (1959), who reported values ranging from 4.7 to 6.0% of the protein as the lysine requirement of young pigs consuming rations of similar protein levels.

Addition of fat to the ration improved gain by 37 g per day. Sewell et al. (1961) and Lowrey et al. (1962) noted that added fat in rations containing similar protein levels to those used in this study was of no advantage. Because of the high, well-balanced amino acid content of these rations, the improvement in growth occurring with energy additions may be expected, even though crude protein content of the rations was low. This conclusion is supported by the work of Lowrey et al. (1963). In general, growth increased with narrowing calorie:amino acid ratios (kcal digestible energy per kg per percentage lysine). Maximum growth of 246 g per day was obtained on the diet containing 0.85% lysine and 5% fat.

Table 9. Experiment 1 — Yorkshire and Lacombe x Yorkshire pigs: gain, feed consumption, and efficiency of feed utilization

Ration	Fat %	Lysine %	Sex	Avg daily gain(g) York	Avg daily gain(g) Lac x York	Avg daily feed(g) York	Avg daily feed(g) Lac x York	Feed/kg gain(kg) York	Feed/kg gain(kg) Lac x York
1	0	0.45	M	86	64	241	273	2.8	4.2
			M	86	64	241	291	2.8	4.5
			F	86	54	323	227	3.7	4.2
			F	86	64	186	200	2.2	3.1
	mean			86	62	247	248	2.9	4.0
2	0	0.65	M	45	173	209	345	4.9	2.0
			M	127	109	386	400	3.0	3.7
			F	164	95	454	264	2.8	2.7
			F	204	109	423	273	2.0	2.5
	mean			135	122	368	321	3.2	2.7
3	0	0.85	M	218	164	464	286	2.1	1.8
			M	64	141	200	286	3.1	2.0
			F	259	204	577	486	2.2	2.4
			F	204	204	373	486	1.8	2.4
	mean			178	178	404	386	2.3	2.2
5	5	0.45	M	54	118	109	400	2.0	3.4
			M	86	77	273	259	3.2	3.4
			F	95	95	309	323	3.2	3.3
			F	118	86	368	291	3.1	3.1
	mean			88	94	265	318	2.9	3.3
6	5	0.65	M	218	182	445	359	2.0	2.0
			M	218	141	445	445	2.0	3.2
			F	141	132	350	373	2.5	2.9
			F	95	164	323	427	3.3	2.6
	mean			168	155	391	401	2.4	2.7
7	5	0.85	M	304	236	604	500	2.0	2.1
			M	259	345	473	695	1.8	2.0
			F	259	150	523	336	2.0	2.2
			F	164	204	454	491	2.8	2.4
	mean			246	234	514	506	2.2	2.2

Table 9A. Fat and sex effects on average daily gain (g) — Experiment 1

Fat (%)	Sex: Male	Sex: Female	mean
0	114	145	130
5	186	141	164
mean	150	143	

Table 9B. Fat and sex effects on average daily feed (g) — Experiment 1

Fat (%)	Sex: Male	Sex: Female	mean
0	300	354	327
5	418	382	400
mean	359	368	

Table 9C. Fat and sex effects on efficiency of feed utilization (kg feed per kg gain) — Experiment 1

Fat (%)	Sex: Male	Sex: Female	mean
0	3.1	2.6	2.8
5	2.4	2.8	2.6
mean	2.8	2.7	

As shown by a significant interaction between fat and sex, the daily gain of the male pigs increased 72 g when the level of fat was raised. However, the gains of the female pigs remained relatively constant at 141 to 145 g per day (Table 9A).

Breed of the pigs did not influence daily gain. The fact that the effect of breed was not significant would seem to contradict the research of Bowland and Berg (1959) that demonstrated Lacombe x Yorkshire pigs outgained Yorkshire pigs over the growing period. However, Bell (1964) states that, on the basis of a study of growth curves, the major difference in growth of crossbred pigs compared to purebred pigs occurs after the pigs have reached 40 lb. (18.2 kg) in weight.

<u>Daily feed consumption</u>

Average daily feed intake increased by an average of 93 g with each increase in the level of lysine in the ration. Therefore, the pigs which gained the most were also eating the most feed. Bowland (1960) has also shown supplementation of rations with lysine will increase consumption of the feed.

Adding 5% fat to the rations increased intake of feed by 73 g per day. Similar observations have been reported by Kuryvial et al. (1961).

In Experiment 1 the analysis of covariance and the analysis of variance differed only with respect to an interaction of fat x sex for daily feed intake. This interaction was found to be significant in the analysis by covariance. Presumably the differences in response between sexes were increased when the data were adjusted to a constant initial weight. The non-significant interaction, as found by the analysis of variance, indicates the daily feed consumption of the males increased by 118 g whereas the increase was only 28 g for the females when 5% fat was added to the ration (Table 9B).

Breed of the pig did not influence consumption of the rations.

Efficiency of feed utilization

An average of 0.6 kg less feed was required per kg of gain with each increase in the lysine level of the ration. These results agree with the work of Bowland (1960), Magruder et al. (1961), and Meade et al. (1965). The results are expected on a theoretical basis because lysine additions improved the amino acid balance of the protein content of the rations.

The failure of fat to significantly improve the feed:gain ratio is in accordance with the results of Peo et al. (1957) and Eusebio et al. (1965). However, when 5% fat was added to the rations fed to the male pigs, the feed required per kg of gain decreased by 0.7 of a kilogram. Efficiency of feed utilization widened from 2.6 to 2.8 when fat was added to the rations fed the female pigs. Thus, a significant fat x sex interaction occurred (Table 9C).

Breed of the pig did not influence the feed:gain ratio.

Table 10. Experiment 1 — Mean squares obtained by analysis of variance and by analysis of covariance

	Analysis of variance				Analysis of covariance			
	df	Avg daily gain	Avg daily feed	Feed/kg gain	df	Avg daily gain	Avg daily feed	Feed/kg gain
Total	45				44			
1 Breed	1	.0015	.0000	0.37	1	.0028	.0100	0.04
2 Lysine	2	.0663**	.1339**	4.91**	2	.0670**	.1402**	4.72**
3 Fat	1	.0157**	.0589**	0.70	1	.0150**	.0531**	0.76
4 Sex	1	.0004	.0009	0.03	1	.0000	.0114	0.01
Interactions								
12	2	.0000	.0024	1.08	2	.0001	.0013	0.83
13	1	.0002	.0048	0.03	1	.0000	.0001	0.00
14	1	.0027	.0183	0.02	1	.0023	.0136	0.00
23	2	.0016	.0061	0.20	2	.0020	.0102	0.26
24	2	.0004	.0024	0.08	2	.0006	.0032	0.08
34	1	.0181**	.0248	2.00*	1	.0194**	.0358*	1.62*
123	2	.0004	.0007	0.51	2	.0003	.0007	0.58
124	2	.0001	.0020	0.38	2	.0001	.0027	0.36
134	1	.0027	.0004	0.75	1	.0014	.0013	1.02
234	2	.0082*	.0360*	0.28	2	.0072*	.0290*	0.35
1234	2	.0050	.0208	0.29	2	.0049	.0187	0.29
Error	22	.0017	.0071	0.37	21	.0017	.0059	0.37

*Significant at $P < 0.05$.

**Significant at $P < 0.01$.

Table 11. Experiment 1 — Marginal means obtained by analysis of variance: gain, feed consumption, and efficiency of feed utilization

Variables	Categories	Avg daily gain g	Avg daily feed g	Feed/kg gain kg
Breed	York	150	364	2.6
	Lac x York	141	364	2.8
Lysine	0.45%	82	268	3.3
	0.65%	145	368	2.8
	0.85%	209	454	2.2
Fat	0.0%	127	327	2.8
	5.0%	164	400	2.6
Sex	Male	150	359	2.8
	Female	145	368	2.7

Daily Gain, Daily Feed, and Efficiency of Feed Utilization — Experiment 2

The data for average daily gain, average daily feed consumption, and efficiency of feed utilization of Hampshire x Yorkshire x Landrace pigs are given in Table 12. The statistical analysis of these data and the marginal means are presented in Tables 13 and 14, respectively.

Daily gain

The lysine additions increased daily gain, which agrees with the observations in Experiment 1. On the basis of the requirements of baby pigs, as defined by the Sub-committee on Swine Nutrition of the National Academy of Sciences — National Research Council (1964), 1.05% lysine in these rations was expected to be equal to or in excess of the needs of these pigs. Although gain was increased by 137 g per day by increasing lysine in the diet from 0.45 to 1.05%, there was no evidence that lysine had reached an optimum level if daily gain is the measure of performance.

The addition of 5% tallow to the rations was found to significantly increase gain if the data were adjusted to a constant initial weight of the pigs. These results agree with those obtained in Experiment 1.

Sex of the pig did not influence daily gain.

The narrowest calorie:lysine ratios gave the maximum gains, indicating the ratio should be at least 3500:1 (kcal digestible energy per kg per unit percentage lysine) (Fig. 1, p.41). This would be in accordance with the research of Robinson and Lewis (1964) which showed the optimum calorie:lysine ratio for finishing pigs was approximately 3500:1 (kcal digestible energy per kg per unit percentage lysine).

Table 12. Experiment 2 — Hampshire x Yorkshire x Landrace pigs: gain, feed consumption, and efficiency of feed utilization

Ration	Fat	Lysine	Sex	Avg daily gain	Avg daily feed	Feed/ kg gain	Ration	Fat	Lysine	Sex	Avg daily gain	Avg daily feed	Feed/ kg gain
	%	%		g	g	kg		%	%		g	g	kg
1	0	0.45	M	23	223	10.3	5	5	0.45	M	64	227	3.5
			M	32	191	5.8				M	54	227	4.1
			F	54	250	4.6				F	23	182	8.5
			F	45	136	3.2				F	77	427	5.6
	mean			39	200	6.0		mean			54	266	5.4
2	0	0.65	M	77	218	2.8	6	5	0.65	M	64	218	3.3
			M	86	273	3.1				M	86	273	3.1
			F	64	177	2.7				F	141	336	2.4
			F	64	200	3.1				F	45	173	4.0
	mean			73	217	2.9		mean			84	250	3.2
3	0	0.85	M	95	218	2.2	7	5	0.85	M	273	500	1.8
			M	86	223	2.6				M	118	291	2.4
			F	118	314	2.7				F	195	323	1.7
			F	164	336	2.1				F	109	336	3.1
	mean			116	273	2.2		mean			174	363	2.2
4	0	1.05	M	218	409	1.9	8	5	1.05	M	236	491	2.0
			M	164	345	2.1				M	150	291	1.9
			F	173	391	2.2				F	182	445	2.4
			F	150	391	2.6				F	182	364	2.0
	mean			176	384	2.2		mean			188	398	2.1

Table 12A. Fat and sex effect on efficiency of feed utilization (kg feed per kg gain) — Experiment 2.

Fat (%)	Sex: Male	Sex: Female	mean
0	3.8	2.8	3.3
5	2.8	3.7	3.2
mean	3.3	3.2	

Daily feed consumption

Feed consumption was increased at the two highest levels of lysine, although the mean feed intake of 391 g on the 1.05% lysine level was not significantly different from the intake of 318 g feed per day on the 0.85% lysine level.

Although fat was not found to be a significant factor influencing feed consumption when the results were analyzed by the analysis of variance, it was determined to be an important factor by the analysis of covariance. When the rations contained 5% fat, the intake of feed was increased.

Feed intake was increased by lysine or fat additions to the rations but these additions were also associated with increased daily gains of the pigs. Therefore, it is likely that the more rapidly growing pigs were eating the most, rather than lysine or fat per se affecting the intake of feed.

Daily feed intake was not affected by sex of the pig.

All of these results agree with those obtained in Experiment 1.

Efficiency of feed utilization

The feed:gain ratio reached a minimum of 2.2 at the 0.85% lysine level in the ration. Therefore, a favourable calorie:lysine ratio was

obtained, with a maximum efficiency reached at a ratio of approximately 4000:1 (Fig. 1, p. 41).

Fat level in the ration and sex of the pig interacted to influence the efficiency of feed utilization. An improvement in efficiency from 3.8 to 2.8 occurred when 5% fat was added to the diet of the male pigs. However, the feed:gain ratio rose from 2.8 to 3.7 when the female pigs ate the same rations (Table 12A).

Table 13. Experiment 2 — Mean squares obtained by analysis of variance and by analysis of covariance

	Analysis of variance				Analysis of covariance			
	df	Avg daily gain	Avg daily feed	Feed/ kg gain	df	Avg daily gain	Avg daily feed	Feed/ kg gain
Total	31				30			
1 Lysine	3	.0303**	.0462**	22.33**	3	.0281**	.0425**	21.98**
2 Fat	1	.0047	.0204	0.05	1	.0060*	.0259**	0.05
3 Sex	1	.0001	.0008	0.03	1	.0001	.0006	0.03
Interactions								
12	3	.0010	.0023	0.25	3	.0006	.0011	0.25
13	3	.0003	.0012	0.20	3	.0004	.0017	0.20
23	1	.0006	.0000	8.20*	1	.0000	.0018	7.60*
123	3	.0017	.0069	6.50**	3	.0009	.0067	6.16*
Error	16	.0018	.0063	1.15	15	.0012	.0040	1.23

*Significant at $P < 0.05$.

**Significant at $P < 0.01$.

Table 14. Experiment 2 — Marginal means* obtained by analysis of variance: gain, feed consumption, and efficiency of feed utilization

Variables	Categories	Avg daily gain g	Avg daily feed g	Feed/ kg gain kg
Lysine	0.45%	45[a]	232[a]	5.7
	0.65%	77[a]	232[a]	3.1[a]
	0.85%	145[b]	318[b]	2.2[a]
	1.05%	182[b]	391[b]	2.2[a]
Fat	0.0%	100	268	3.3
	5.0%	127	318	3.2
Sex	Male	114	291	3.3
	Female	114	300	3.2

*Means with common superscripts are not significantly different from each other ($P < 0.05$).

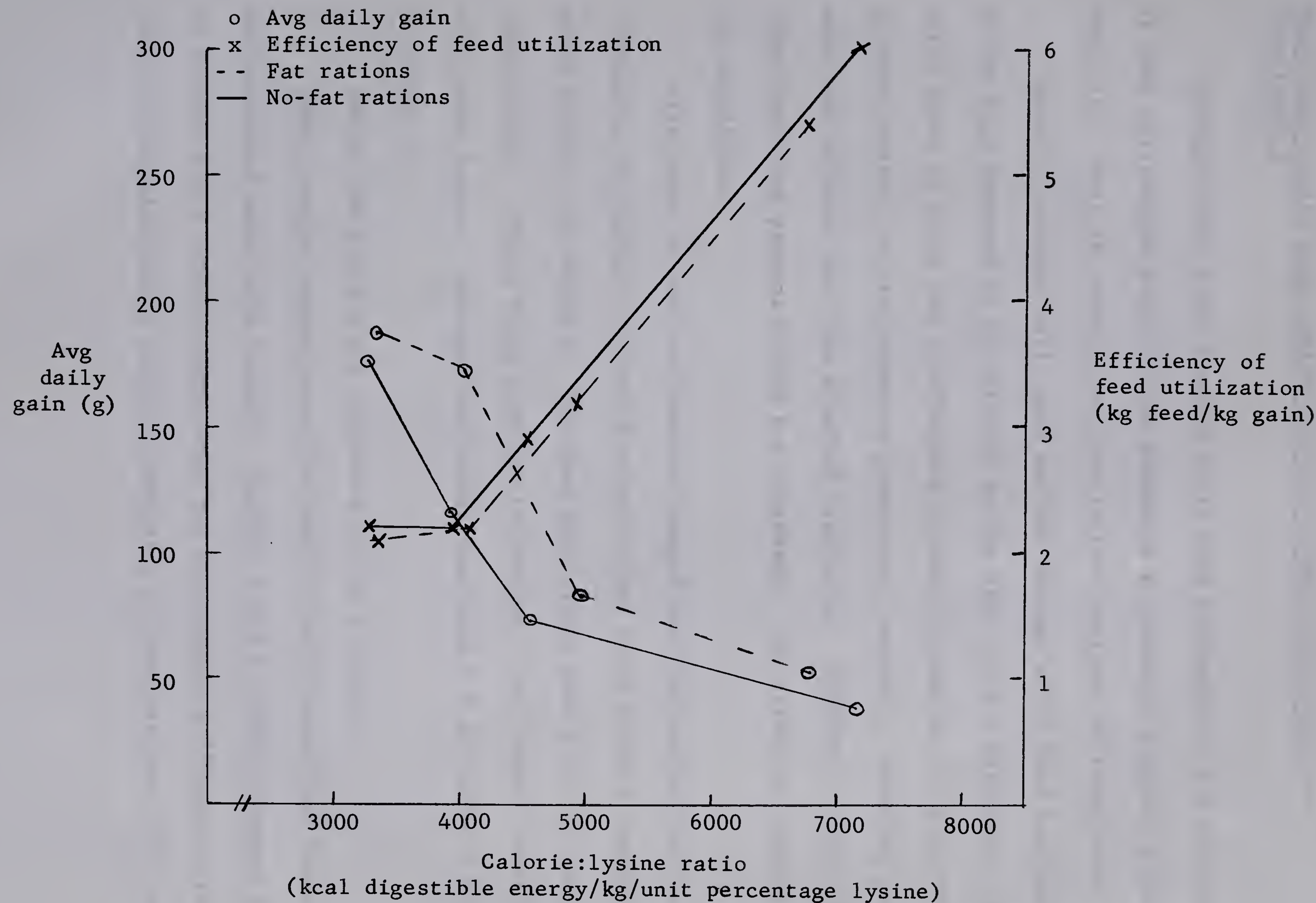

Figure 1. Experiment 2 — Relationship of gain and the efficiency of feed utilization to the calorie: lysine ratio

Daily Gain, Daily Feed, and Efficiency of Feed Utilization — Experiment 3

Average daily gain, average daily feed consumption, and efficiency of feed utilization data for the Hampshire x Yorkshire pigs are given in Table 15. Table 16 contains the statistical analysis of these data.

Both the average daily gain and the average daily feed consumption of the pigs appeared to be affected by the diet, with a difference in daily gains of 149 g and a difference in daily intake of 147 g occurring between ration 3 and the standard prestarter, ration 9. Superior performance was achieved with the standard prestarter. However, because of the large variation present within the treatments, the effect of rations was not significant.

Efficiency of feed utilization changed with the ration fed, but no difference in treatment occurred among rations 4 and 8, which contained 0.6% added lysine, and ration 9. The feed:gain ratios were 2.2, 2.0, and 1.8, respectively. Ration 9 was superior to rations 3 and 7 which contained 0.4% added lysine. Average feed conversions were 2.8 on ration 3 and 2.5 on ration 7.

Sex of the pig did not influence any of the data.

These results demonstrated the benefits of a ration that has a high, well-balanced amino acid content. Rations 4 and 8, which averaged 15.1% in protein and 1.03% in lysine, were not significantly different from a ration of similar energy content containing 22% protein and 1.18% lysine.

Table 15. Experiment 3 — Hampshire x Yorkshire pigs: gain, feed consumption, and efficiency of feed utilization

Ration		Avg daily gain	Avg daily feed	Feed/kg gain*
		g	g	kg
3		114	336	3.0
		114	336	3.0
		200	482	2.4
		86	277	3.2
	mean	128	358	2.8[c]
4		264	550	2.1
		182	445	2.4
		195	468	2.4
		95	204	2.1
	mean	184	417	2.3[ab]
7		200	454	2.3
		182	409	2.2
		145	391	2.7
		173	500	2.9
	mean	175	438	2.5[bc]
8		245	532	2.2
		141	354	2.5
		277	368	1.3
		118	264	2.2
	mean	195	380	2.0[ab]
9		359	618	1.7
		277	514	1.8
		236	414	1.7
		236	473	2.0
	mean	277	505	1.8[a]

*Means with common superscripts are not significantly different from each other ($P < 0.05$).

Table 16. Experiment 3 — Mean squares obtained by analysis of variance

	df	Avg daily gain	Avg daily feed	Feed/kg gain
Total	18			
1 Ration	4	.0117	.0130	.73**
2 Sex	1	.0049	.0251	.00
12	4	.0024	.0086	.18
Error	9	.0041	.0107	.10

**Significant at $P < 0.01$.

GENERAL DISCUSSION

A consistent improvement in gain, daily feed intake, and efficiency of feed utilization was obtained when the basal diet was supplemented with lysine. With additions of lysine to the diet, an increase in digestibility of lysine and in retention of nitrogen was observed. Therefore, greater gains were probably obtained because more of the nitrogen in the ration could be used for building up body protein.

The addition of fat increased daily gain and daily feed intake in both Experiments 1 and 2. However, the increase in daily feed was felt to be a result of the more rapidly growing pigs eating the most feed. This fact is borne out in that the efficiency of feed utilization was unchanged. Therefore, an increase in energy content did not decrease total feed consumption and reduce the amount of feed required per unit of gain, as would be expected from previous research. Possibly the baby pigs were unable to utilize the added fat until the last 3 weeks on the experiments because lipase activity of pancreatic tissue is low until 6 to 7 weeks of age (Hartman et al., 1961). Alternatively, it may be suggested that the pigs ate more feed because fat improved palatability. At all levels of lysine supplementation, fat additions increased gains. This would be expected if the pigs were eating more total feed because more lysine would be available to meet the pigs' requirements and increased gains would be expected to result.

These results support the hypothesis that lysine content should be related to the energy content of the ration. Maximum performance was obtained on the narrowest calorie:lysine ratios.

More nitrogen and energy was digested and more nitrogen was retained by the Yorkshire than by the Lacombe x Yorkshire pigs. However, the major

differences occurred at the 5th week and by the 9th week the differences were small. Because of these differences in ability to digest energy and nitrogen, the possibility exists that the protein and energy content of the rations for the crossbreds should be higher than for the purebred pigs in order that requirements be met. The advantages that the Yorkshire pigs had in digestibility and retention did not appear in daily gains. Therefore, the crossbred pigs appeared to be more efficient in transferring the digested nutrients to body tissues.

Experiment 3 clearly demonstrated the advantages of balanced, high levels of amino acids in the diet. Rations low in protein, but supplemented to balance the amino acid content and to raise the amino acid content to meet the requirements of the pigs, were found to support performance of pigs equivalent to that of pigs consuming a ration much higher in protein level. Therefore, amino acid supplementation of rations can be effectively used to make more efficient use of protein nitrogen of feedstuffs and thereby decrease wastage of protein.

GENERAL SUMMARY

Experiments were designed to permit the study of the effect of energy and lysine additions to baby pig rations and to study the interrelationships among lysine, protein, and energy.

Lysine digestibility was improved by lysine additions to the ration and with increasing age of the pig. An interaction showed this increase with age was limited to the male pigs. The digestibility of lysine was not influenced by fat levels in the ration or by breed of the pig.

The pigs digested more of the nitrogen of the ration at 9 weeks of age than they did at 5 weeks of age. More of the protein was digested by Yorkshires than by the Lacombe x Yorkshire pigs, but an interaction indicated this difference was greatest when the pigs were 5 weeks of age. Apparent digestible nitrogen coefficients were unchanged by the lysine or fat levels in the ration or by the sex of the pig.

Neither the lysine or fat levels in the ration nor the sex of the pig had any effect on the digestibility of energy. More of the energy content of the ration was digested by the Yorkshire pigs than by the Lacombe x Yorkshires, but an interaction showed this difference occurred before the pigs reached 9 weeks of age.

Lysine, but not fat, additions increased the retention of nitrogen of the baby pigs. Higher nitrogen retention values were obtained for the Yorkshire pigs than for the Lacombe x Yorkshire pigs. An interaction indicated these differences in breed response were small when the pigs reached 9 weeks of age. The retention of nitrogen was independent of the sex of the pig.

Lysine or fat additions consistently increased daily gain and daily feed consumption. In Experiment 1, a fat x sex interaction indicated

fat additions resulted in a greater response with the male pigs than with the female pigs. Breed of the pig, in Experiment 1, and sex of the pig, in Experiment 2, had no influence on either of the measures.

Lysine supplementation also improved the efficiency of feed utilization. A fat x sex interaction showed fat additions improved the efficiency of feed utilization for the male pigs but not for the female pigs. Breed of the pig did not influence the feed:gain ratio.

On the basis of these results, a lysine content of 1.07% in the ration is low if the energy level is 3300 or 3530 kcal per kg of diet. The results indicated that it is more important to define the requirements for amino acids than the requirements for protein. The protein content of the rations can be extremely variable and give similar performance, but this is not true for amino acid content. That is, a lower total protein in the ration is required if the amino acid content is supplied by high-quality protein ingredients than if the ingredients are poorly balanced in amino acid levels. It would appear that the amino acid levels should be recommended on the basis of their relationships to the energy level of the ration.

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